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Chemical composition of A and F dwarfs members of the Pleiades open cluster⋆,⋆⋆
(Research Note)

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ABSTRACT

Aims. We derive the abundances of 18 chemical elements for 16 A-dwarf, both normal and chemically-peculiar, and 5 F-dwarf members of the Pleiades open cluster to place constraints on evolutionary models.

Methods. Abundances and rotational and microturbulent velocities were derived by fitting synthetic spectra to high-resolution ($R \sim 42\,000$ and $R \sim 75\,000$) observations of high signal-to-noise ratio (S/N).

Results. The abundances exhibit correlation with neither the effective temperature nor the projected rotational velocity. Interestingly, A stars exhibit larger star-to-star variations in C, Sc, Ti, V, Cr, Mn, Sr, Y, Zr and Ba, than F stars. F stars have solar abundances of almost all elements. In A stars, the abundances of Si, Ti and Cr are correlated with that of Fe, and the [X/Fe] ratios are solar for these three elements.

The derived abundances are compared with the predictions of evolutionary models for the age of Pleiades (100 Myr). For F stars, small predicted underabundances of light elements and overabundances of Cr, Fe and Ni are confirmed by our findings. For A stars, the predicted overabundances in iron-peak elements are confirmed for a few stars only.

Conclusions. The large scatter in the abundances of A stars, discovered previously in the Hyades, Coma Berenices, UMa group, and in field stars, appears to be a characteristic property of dwarf A stars. Hydrodynamical processes competing with radiative diffusion in the radiative zone of A dwarfs, could account for the scatter in abundances that we determine.

Key words. stars: abundances – stars: rotation – diffusion – Galaxy: open clusters and associations: individual: Pleiades

1. Introduction

This paper is the second in a series about the abundances of 18 chemical elements in A and F dwarfs in open clusters of different ages. In a previous study, the abundances of similar elements were derived for 11 A and 11 F dwarfs members of the Coma Berenices open cluster by Gebran et al. (2008, hereafter refered to as Paper I). The aims of this project are twofold: to improve our knowledge of the chemical composition of A dwarfs (normal and CP stars), and to set constraints on self-consistent evolutionary models that include hydrodynamical and particle transport processes. At the age of Coma Berenices (about 450 Myr, Bounatiro & Arimoto 1993), A stars have spent more time on the Main Sequence than at the age of the Pleiades (around 100 Myr, Meynet et al. 1993). Comparison of the abundances derived for A and F stars in these 2 clusters should help address the expected evolution of abundances with time predicted in the frame of the diffusion theory (Richer et al. 2000).

High-resolution spectroscopy of A and F stars in the Pleiades is possible using 2-m class telescopes down to magnitude $V = 9$, wich corresponds to the earliest F stars. The distance to the Pleiades is about 134 ± 3 pc (Percival et al. 2005). In Table 1, we show previous abundance determinations of A, F and G dwarfs in the Pleiades. Lithium abundances were first derived by Pilachowski et al. (1987) for A, F and G dwarfs, and then by Ford et al. (2002) for G and K stars. Carbon and iron abundances were determined in 12 F dwarfs, by Friel & Boesgaard (1990) and Boesgaard & Friel (1990), respectively. They derived a mean iron abundance of $\langle[\mathrm{Fe/H}]\rangle = -0.034 \pm 0.024$ dex. Beryllium abundances were derived by Boesgaard et al. (2003) for 14 F and G dwarfs. Burkhart & Coupry (1997) determined the abundances of Li, Al, Si, S, Fe, Ni and Eu for 5 normal A and 3 Am stars. Quite unexpectedly, they derived a similar iron abundance for A and Am stars, which is about twice the value determined for F stars. Hui-Bon-Hoa & Alecian (1998) determined the abundances of Mg, Ca, Sc, Cr, Fe and Ni for 9 A-Am stars in the Pleiades.

We derive the abundances of 18 chemical elements (C, O, Na, Mg, Si, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Sr, Y, Zr and Ba.) for 16 A and 5 F dwarfs in the Pleiades open cluster. As in Paper I, we search for correlations of the individual abundances with effective temperature (T_{eff}), projected rotational velocity ($v_{\mathrm{e}} \sin i$) and iron abundance. Any correlation would be valuable to theoretical studies of photospheric abundances. The

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⋆ Based on observations performed at the Observatoire de Haute-Provence (France).

⋆⋆ Tables 3 and 4 are only available in electronic form at http://www.aanda.org

Table 1. Previous abundance determinations for the Pleiades A, F and G dwarfs.

Reference	Stars studied	Chemical elements
Pilachowski et al. (1987)	18 A, F, G	Li
Burkhart & Coupry (1997)	8 A-Am	Li, Al, Si, S, Fe, Ni, Eu
Hui-Bon-Hoa & Alecian (1998)	9 A-Am	Mg, Ca, Sc, Cr, Fe, Ni
Boesgaard & Friel (1990)	12 F	Fe
Friel & Boesgaard (1990)	12 F	C
Boesgaard et al. (2003)	14 F and G	Be
Ford et al. (2002)	11 G and K	Li

Table 2. Data on the programme stars. Spectral type are taken from the SIMBAD and WEBDA online database. $T_{\rm eff}$ and $\log g$ are those determined by UVBYBETA code. $v_{\rm e} \sin i$ and $\xi_{\rm t}$ are determined as explained in Sect. 3. References (a), (b), (c) and (d) are Couteau & Gili (1994), Breger (1972), Abt & Levato (1978) and Renson (1990).

HII	HD	Type	m_v	$T_{\rm eff}$ (K)	$\log g$	$v_{\rm e} \sin i$ km s^{-1}	$\xi_{\rm t}$ km s^{-1}	Remarks
157	23157	A5V	7.95	7514	4.26	56	2.60	SB (a)
158	23156	A7V	8.23	7940	4.23	32.5	2.70	δ Scuti (b)
697	23375	A9V	8.58	7395	4.22	88	2.30	
1362	23607	A7V	8.25	8055	4.32	18.9	3.10	δ Scuti (b), Am (d)
1397	23631	A2V	7.30	9613	4.34	7.5	2.10	SB, Am (c)
1876	23763	A1V	6.96	8999	4.19	100	2.00	
2415	23924	A7V	8.10	8144	4.29	33.5	2.70	
2488	23948	A0	7.54	9083	4.35	118	2.30	
5006	22615	Am	6.50	8407	3.83	29.5	4.00	$\notin$ Pleiades (d)
531	23325	Am	8.57	7638	4.23	80	2.50	
1375	23629	A0V	6.28	9940	4.32	162	1.55	SB
1380	23632	A1V	7.02	9616	4.22	200	1.50	
2195	23863	A7V	8.15	7911	4.10	157	2.50	
1028	23489	A2V	7.38	9078	4.25	120	1.90	
1993	23791	A8V	8.38	7796	4.32	75	3.20	
717	23387	A1V	7.19	9581	4.22	21	0.50	SB
605	23351	F3V	9.03	6863	4.38	14.8	1.45	
1357	23609	F8IV	6.99	6492	4.28	9.8	1.75	
338	23247	F3V	9.06	6948	4.47	43.5	2.00	
1766	23732	F4V	9.21	6837	4.54	25	1.70	
1122	23511	F4V	9.28	6730	4.63	30.5	1.60	

derived abundances are compared with the predictions of self-consistent evolutionary models.

2. Program stars, observations and data reduction

Twenty-one stellar members of the Pleiades cluster were observed from the 5th to the 11th of January 2004 and from the 30th of November to the 4th of December 2006. We selected stars that were evenly distributed in terms of mass in the Main Sequence. The selected 15 A stars amount to about half the total number of A dwarfs in the Pleiades. These stars were observed using ELODIE and SOPHIE, which are two échelle spectrographs at the Observatoire de Haute-Provence (OHP). ELODIE is a fiber-fed cross-dispersed echelle spectrograph mounted on the 1.93-m telescope at OHP (Baranne et al. 1996). An ELODIE spectrum extends from 3850 to 6811 Å at a resolving power of about 42 000. ELODIE was replaced by SOPHIE in September 2006. SOPHIE spectra cover the wavelength interval from 3820 to 6930 Å in 39 orders with two different spectral resolutions: the high resolution mode HR (R = 75 000) and the high efficiency mode HE (R = 39 000). SOPHIE is about 2 mag more sensitive in the V band than ELODIE. Using SOPHIE, we were therefore able to acquire spectra in HR-mode that had a signal-to-noise ratio of between 100 and 300, with an exposure time of lower than 75 min. The five early F stars, which are all fainter than V = 9 mag, were observed using SOPHIE. The basic data of these stars are collected in Table 2. The Hertzsprung and Henry Draper identifications appear in Cols. 1 and 2. In Col. 3, we present the spectral type, and in Col. 4, the apparent visual magnitude. Effective temperatures ($T_{\rm eff}$) and surface gravities ($\log g$), which are derived using $uvby\beta$ photometry, are provided in Cols. 5 and 6. The projected rotational velocities and microturbulence velocities are shown in Cols. 7 and 8. Comments about the membership, binarity and pulsation appear in the last column. The rotational velocities of these stars were derived to range between 7.5 km s^{-1} and 200 km s^{-1}, and six A stars were found to rotate with a $v_{\rm e} \sin i$ larger than 100 km s^{-1}. According to the CCDM catalogue (Dommanget & Nys 1995), HD 23387 is the primary in a spectroscopic binary. Its companion, located at 0.3 arcsec, has a visual magnitude V = 9, and should be responsible for about 20% of the light in the spectrum. The spectral type of this companion is unknown. Careful inspection of the spectrum of HD 23387 does not reveal lines that could be attributed to a companion of a later spectral type in contrast to that of the primary. The abundances derived for HD 23387 should be interpreted with caution.

The reduction of ELODIE's spectra was explained fully in Paper I, and follows the method of Erspamer & North (2002). A similar reduction procedure was applied to SOPHIE spectra. The correction for scattered light was found to be about 1% in the blue part of the spectrum and less elsewhere.

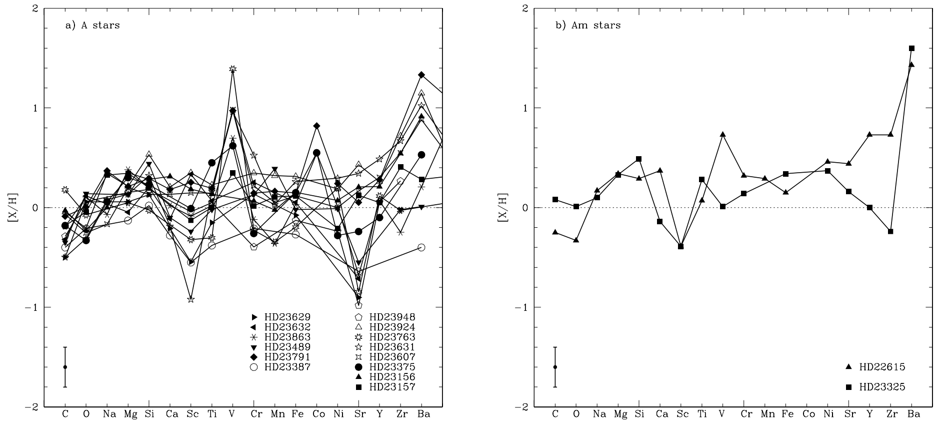

Fig. 1. Abundance patterns of normal A **a)** and Am **b)** stars members of Pleiades Cluster. The horizontal dotted line represents the solar value.

3. Abundance analysis

3.1. Method and input data

The most appropriate method to derive abundances is spectrum synthesis because several of the investigated stars are fast rotators. The iterative method of Takeda (1995) was used to derive the abundances of 18 chemical elements. The method fits in an iterative way synthetic spectra to the observed normalized spectra, and minimizes the chi-square statistic between models and observations (see Gebran et al. 2008, for a detailed discussion).

The effective temperatures and surface gravities were determined using the UVBYBETA code developped by Napiwotzki et al. (1993). This code is based on the Moon & Dworetsky (1985) grid, which calibrates the $uvby\beta$ photometry in terms of $T_{\rm eff}$ and $\log g$. The photometric data were taken from Hauck & Mermilliod (1998). The estimated errors on $T_{\rm eff}$ and $\log g$, are ±125 K and ±0.20 dex, respectively. The derived effective temperatures and surface gravities are shown in Cols. 5 and 6 of Table 2.

LTE model atmospheres were calculated using Kurucz's ATLAS9 code (Kurucz 1992). The solar abundances used in ATLAS9 and in the synthetic spectra computation were taken from Grevesse & Sauval (1998). This version of ATLAS9 uses the new opacity distribution function (ODF) (Castelli & Kurucz 2003). The microturbulent velocity is constant with depth and was adopted as prescribed by Smalley (2004). For stars with $T_{\rm eff} \leq 8500$ K, convection was taken into account in the model computations using a mixing-length ratio equal to 1.25.

We used the same linelist as in Paper I (270 transitions for 18 elements). The LTE assumption is justified for most lines studied because the lines are weak and form deep inside the atmospheres in which the conditions of LTE should hold. A few lines of CI, MgII and BaII, which we analyse here, are affected by non-LTE effects (Gebran et al. 2008). The derived abundances for these elements appear in brackets in the online Tables 3 and 4.

3.2. Results

Projected rotational velocities, microturbulent velocities and abundances of 18 chemical elements were determined following a similar procedure to that used in Paper I (Sect. 3.2). The rotational and microturbulent velocities were derived using a set of weak and strong unblended lines of iron and the MgII triplet at λ4481 Å (Sect. 3.2.1 of Paper I). For seven stars in common between both studies, our derived rotational velocities are in good agreement with the results of Hui-Bon-Hoa & Alecian (1998). The microturbulent velocities were found to comply with the prescription of Smalley (2004). To provide an independent assessment of our results, we derive the abundances in addition using the code SYNSPEC48 (Hubeny & Lanz 1992). The abundances derived using Takeda's procedure were found to agree within their uncertainties with those derived using SYNSPEC48. The abundances presented in the online tables (3 and 4) are those derived using Takeda's iterative procedure. The measurement of the errors in the abundances, is described in the Appendix of Paper I.

4. Discussion and conclusion

4.1. Search for correlations with stellar parameters

The behaviour of the abundances in relation to stellar parameters (effective temperature, apparent rotational velocity and also iron abundance) was investigated. No strong correlation was found between any derived abundance and either $T_{\rm eff}$ or $v_{\rm e} \sin i$. However, we found large star-to-star variations for several abundances determined for the A stars, in particular for C, Sc, Ti, Cr, Fe, Sr, Y, Zr and Ba. This behaviour is evident in Fig. 1 where abundances of chemical elements are displayed for all A stars. It can also be readily observed in graphs where [X/H] is presented with effective temperature: in these graphs, A stars show abundances that are more scattered about the mean value than for F stars. We present our result for iron in Fig. 2. Similar star-to-star variations in the abundances of several chemical elements have been found in A stars in other clusters or moving groups: in the Hyades (Varenne & Monier 1999), in the UMa group (Monier 2005), and in the Coma cluster (Gebran et al. 2008).

The two Am stars (HD 23325 and HD 22615) analysed in this study are both underabundant in scandium. Calcium is underabundant in HD 23325 but overabundant in HD 22615 by about ~0.37 dex. Cr, Fe, Ni, Sr and Ba are enhanced in both of these Am stars. We confirm that HD 23631 (A2V) should be classified as an Am star as already suggested by Conti (1968), Gray & Garrison (1987), and Renson (1990): for this star, we derived an apparent rotational velocity of 7.5 km s^{-1}, deficiencies in both calcium and scandium (0.19 dex and 0.92 dex respectively), and enrichments in both iron-peak and heavy elements. HD 23631 was found to be a short-period (P = 7.34 days) binary, Am star by Conti (1968). Gray & Garrison (1987)

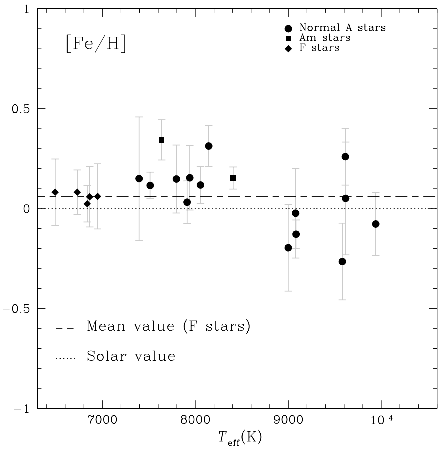

Fig. 2. [Fe/H] versus $T_{\rm eff}$ for the 21 stars. The dotted line represents the solar value and the dashed line represents the mean abundance of iron for the F dwarfs. F stars are depicted as diamonds, Am stars as squares and normal A stars as circles.

classified HD 23631 as an A0mA1Va, using intermediate-resolution spectra.

In normal A stars, the ratios [C/Fe] and [O/Fe] are found to be anticorrelated with [Fe/H], which is also the case in Coma Berenices. The abundances of Mg, Si, Ti and Cr are found to be correlated with that of Fe, with correlation coefficients of 0.63, 0.78, 0.84 and 0.65 respectively. The ratios [X/Fe] for these elements are close to solar as already found for field A stars for Si and Ti (Lemke 1989; Hill & Landstreet 1993).

Concerning F stars, we found a mean iron abundance of $\langle[\mathrm{Fe/H}]\rangle = 0.06 \pm 0.02$ dex, using FeII lines, which is based on the 5 stars observed. This value is slightly larger than that derived by Boesgaard & Friel (1990) in their analysis of 12 F stars: −0.034 dex based on their analysis of 15 Fe I lines. This difference could occur because different lines and/or effective temperatures and surface gravities, were used.

4.2. Evolutionary models

The derived abundances can be compared with the predictions of evolutionary models. These abundances provide constrain on the physics included in the code. For F stars, the models calculated by Turcotte et al. (1998) include radiative diffusion and gravitational settling for 28 chemical elements ($Z \leq 28$). At the age of the Pleiades cluster (100 Myr), these models predict slight underabundances of carbon and oxygen for stars with $T_{\rm eff} > 6500$ K, which are confirmed in our data. However, the predicted underabundances of Mg, Si and Ca are not found in our analysis. The predicted slight overabundances for Cr, Fe and Ni are observed for the five F stars analysed. The overall trends for F stars, which are slight underabundances of light elements and overabundances of iron-peak elements, agree well with the model predictions (except for a few elements) suggesting that the appropriate astrophysical prescriptions for F stars, are being included in the code.

For A stars, we compare our results with the predictions of the Richer et al. (2000) models, which include turbulent diffusion in addition to radiative diffusion. Inspection of their Figs. 10 and 11 reveals that at the age of the Pleiades, C and O should be slightly underabundant by about −0.1 dex, and the iron-peak elements be slightly overabundant at a level between 0.1 and 0.4 dex. The derived abundances for C, O and iron-peak elements in our analysis, agree well with these levels of deficiency and enrichment.

The star-to-star scatter of abundances for the 16 A stars analysed here, has been detected previously in other open clusters and for a few field A stars. It appears to be a characteristic property of dwarf A and F stars and strongly suggests that hydrodynamical processes, competing with radiative and turbulent diffusion, must be at work in the radiative zones of these stars (for a review, see Zahn 2005). To measure this scatter, spectroscopic data for the remaining A and F stars in the Pleiades, will be required. Non-LTE analysis should in addition be performed to yield more accurate abundances for C, Mg and Ba because many lines that we analyse here corresponding to these elements, are affected by non-LTE effects.

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Table 3. Abundances relative to hydrogen and to the solar value, $[\frac{X}{H}] = \log(\frac{X}{H})_{\star} - \log(\frac{X}{H})_{\odot}$ for the A stars. The solar values are those of Grevesse & Sauval (1998). The HD numbers in italics are those for which the uncertainties were calculated, as described in Appendix A of Paper I. For the others, the quantities labeled as σ are standard deviations. The lines of the elements in brackets should be considered to be affected by non-LTE.

HD	SpT	⟨CI⟩	$\sigma_{\rm C}$	OI	$\sigma_{\rm O}$	NaI	$\sigma_{\rm Na}$	⟨MgII⟩	$\sigma_{\rm Mg}$	SiII	$\sigma_{\rm Si}$
HD 23157	A5V	–0.18	0.05	–0.04	0.14	0.33	0.06	0.34	0.32	0.20	0.09
HD 23156	A7V	–0.03	0.07	–0.23	0.20	0.00	0.11	0.35	0.32	0.28	0.19
HD 23325	Am	0.08	0.04	0.01	0.09	0.10	0.16	0.33	0.16	0.49	0.11
HD 23375	A9V	–0.18	0.40	–0.33	0.14	0.06	0.27	0.30	0.32	0.23	0.33
HD 23607	A7V	–0.07	0.10	–0.25	0.01	–0.17	0.21	0.20	0.32	0.13	0.07
HD 23631	A2V	–0.50	0.04	–0.31	0.05	0.08	0.12	0.13	0.18	0.32	0.10
HD 23763	A1V	0.18	0.31	–0.07	0.06	–	–	0.05	0.21	–0.02	0.16
HD 23924	A7V	–0.05	0.11	–0.21	0.23	0.34	0.21	0.21	0.30	0.53	0.09
HD 23948	A0	–0.29	0.07	0.06	0.06	–	–	0.15	0.09	0.18	0.13
HD 22615	Am	–0.25	0.08	–0.22	0.06	0.17	0.06	0.34	0.13	0.29	0.08
HD 23629	A0V	–0.50	0.10	0.06	0.06	–	–	0.06	0.34	0.13	0.08
HD 23632	A1V	–0.32	0.11	0.12	0.01	–	–	–0.05	0.20	0.20	0.22
HD 23863	A7V	–0.19	0.11	0.11	0.05	–0.07	0.19	0.38	0.32	–	–
HD 23489	A2V	–0.35	0.08	0.14	0.06	–	–	0.13	0.15	0.44	0.26
HD 23791	A8V	–0.09	0.26	0.00	0.14	0.37	0.08	0.21	0.12	0.29	0.04
HD 23387	A1V	–0.40	0.05	–0.21	0.04	–	–	–0.13	0.09	0.02	0.09

HD	SpT	CaII	$\sigma_{\rm Ca}$	ScII	$\sigma_{\rm Sc}$	TiII	$\sigma_{\rm Ti}$	VII	$\sigma_{\rm V}$	CrII	$\sigma_{\rm Cr}$
HD 23157	A5V	–	–	–0.13	0.11	0.00	0.11	0.35	0.46	0.02	0.09
HD 23156	A7V	0.31	0.12	0.19	0.22	0.13	0.13	–	–	0.07	0.09
HD 23325	Am	–0.14	0.30	–0.39	0.22	0.28	0.15	0.01	0.29	0.14	0.20
HD 23375	A9V	–	–	–0.01	0.14	0.45	0.24	–	–	–0.26	0.28
HD 23607	A7V	0.13	0.44	0.15	0.10	0.14	0.25	0.98	0.03	0.22	0.21
HD 23631	A2V	–0.19	0.05	–0.92	0.05	0.16	0.22	0.96	0.06	0.52	0.17
HD 23763	A1V	–	–	–0.32	0.33	–0.30	0.15	1.39	0.08	–0.23	0.28
HD 23924	A7V	0.21	0.22	0.35	0.17	0.23	0.22	–	–	0.35	0.08
HD 23948	A0	–	–	–0.04	0.13	0.05	0.08	–	–	–0.39	0.21
HD 22615	Am	0.37	0.10	–0.39	0.10	0.07	0.07	0.96	0.12	0.30	0.10
HD 23629	A0V	–0.21	0.09	–0.54	0.34	–0.15	0.13	–	–	0.14	0.17
HD 23632	A1V	–0.11	0.04	0.34	0.09	0.07	0.22	–	–	0.25	0.14
HD 23863	A7V	0.02	0.40	–0.08	0.21	0.02	0.20	0.70	0.11	–0.12	0.36
HD 23489	A2V	–0.10	0.14	–0.24	0.26	–0.02	0.18	–	–	0.13	0.18
HD 23791	A8V	0.18	0.06	0.25	0.42	0.19	0.22	0.97	0.18	0.15	0.21
HD 23387	A1V	–0.28	0.14	–0.55	0.09	–0.38	0.17	–	–	–0.21	0.12

HD	SpT	MnI	$\sigma_{\rm Mn}$	FeII	$\sigma_{\rm Fe}$	CoI	$\sigma_{\rm Co}$	NiI	$\sigma_{\rm Ni}$	SrII	$\sigma_{\rm Sr}$
HD 23157	A5V	0.11	0.20	0.12	0.07	–	–	–0.21	0.10	0.12	0.34
HD 23156	A7V	–0.02	0.08	0.15	0.16	–	–	0.07	0.15	0.21	0.07
HD 23325	Am	–	–	0.34	0.10	–	–	0.37	0.17	0.16	0.26
HD 23375	A9V	–	–	0.15	0.31	0.55	0.08	–0.28	0.33	–0.24	0.07
HD 23607	A7V	0.05	0.12	0.12	0.09	–	–	0.00	0.16	0.17	0.01
HD 23631	A2V	0.03	0.08	0.26	0.14	–	–	0.29	0.11	0.34	0.09
HD 23763	A1V	–0.35	0.37	–0.20	0.22	–	–	0.19	0.20	–0.84	0.34
HD 23924	A7V	0.32	0.09	0.31	0.10	–	–	0.19	0.15	0.43	0.15
HD 23948	A0	–	–	–0.13	0.07	–	–	–0.24	0.27	–0.98	0.24
HD 22615	Am	0.29	0.10	0.15	0.06	–	–	0.46	0.11	0.44	0.30
HD 23629	A0V	–	–	–0.08	0.16	–	–	–	–	–0.90	0.05
HD 23632	A1V	–	–	0.05	0.28	–	–	–	–	–0.71	0.20
HD 23863	A7V	–0.36	0.27	0.03	0.11	0.54	0.08	0.01	0.22	–0.68	0.39
HD 23489	A2V	0.39	0.19	–0.02	0.22	–	–	–0.01	0.24	–0.55	0.23
HD 23791	A8V	0.16	0.17	0.15	0.17	0.82	0.08	0.24	0.34	0.05	0.10
HD 23387	A1V	–	–	–0.27	0.19	–	–	–	–	–0.64	0.04

HD	SpT	YII	$\sigma_{\rm Y}$	ZrII	$\sigma_{\rm Zr}$	⟨BaII⟩	$\sigma_{\rm Ba}$
HD 23157	A5V	0.05	0.11	0.41	0.14	0.28	0.16
HD 23156	A7V	0.21	0.05	0.54	0.05	0.91	0.14
HD 23325	Am	0.00	0.18	–0.24	0.24	1.60	0.17
HD 23375	A9V	–0.10	0.13	–	–	0.53	0.04
HD 23607	A7V	0.30	0.09	0.55	0.14	0.88	0.13
HD 23631	A2V	0.49	0.06	0.67	0.11	1.02	0.01
HD 23763	A1V	0.12	0.36	–0.03	0.11		–
HD 23924	A7V	0.26	0.17	0.72	0.10	1.15	0.27
HD 23948	A0	0.06	0.14	0.27	0.25		–
HD 22615	Am	0.73	0.13	0.73	0.16	1.43	0.18
HD 23629	A0V	–	–	–	–		–
HD 23632	A1V	–	–	–	–		–
HD 23863	A7V	0.07	0.14	–0.25	0.05	0.21	0.28
HD 23489	A2V	–	–	–0.02	0.16	0.01	0.17
HD 23791	A8V	0.28	0.26	–	–	1.33	0.14
HD 23387	A1V	–	–	–	–	–0.40	0.17

Table 4. Abundances relative to hydrogen and to the solar value, $[\frac{X}{H}] = \log(\frac{X}{H})_\star - \log(\frac{X}{H})_\odot$ for the F stars. The HD numbers in italics are those for which the uncertainties have been calculated as explained in Appendix A of Paper I. For the others, the quantities labeled as σ are standard deviations. The lines of the elements in brackets should be considered to be affected by non-LTE.

HD	SpT	⟨CI⟩	$\sigma_{\rm C}$	OI	$\sigma_{\rm O}$	NaI	$\sigma_{\rm Na}$	⟨MgII⟩	$\sigma_{\rm Mg}$	SiII	$\sigma_{\rm Si}$
HD 23351	F3V	–0.06	0.12	–0.34	0.18	–0.20	0.16	0.14	0.36	0.05	0.10
HD 23609	F8IV	0.00	0.13	–0.26	0.04	0.22	0.09	0.08	0.36	0.23	0.07
HD 23247	F3V	–0.07	0.12	–0.03	0.15	–0.14	0.17	0.43	0.36	0.35	0.06
HD 23732	F4V	–0.06	0.06	0.08	0.32	–0.15	0.14	0.21	0.36	0.16	0.12
HD 23511	F4V	–0.06	0.08	–0.01	0.38	–0.03	0.30	0.33	0.36	0.34	0.09

HD	SpT	CaII	$\sigma_{\rm Ca}$	ScII	$\sigma_{\rm Sc}$	TiII	$\sigma_{\rm Ti}$	VII	$\sigma_{\rm V}$	CrII	$\sigma_{\rm Cr}$
HD 23351	F3V	0.00	0.10	–0.01	0.22	0.07	0.21	0.30	0.13	0.03	0.13
HD 23609	F8IV	0.36	0.20	0.14	0.11	0.06	0.14	0.64	0.26	0.15	0.09
HD 23247	F3V	0.00	0.02	–0.05	0.22	0.12	0.25	0.57	0.27	0.04	0.12
HD 23732	F4V	0.31	0.13	–0.05	0.21	0.06	0.21	0.44	0.39	0.02	0.15
HD 23511	F4V	0.33	0.17	0.06	0.27	0.14	0.22	0.35	0.32	0.08	0.14

HD	SpT	MnI	$\sigma_{\rm Mn}$	FeII	$\sigma_{\rm Fe}$	CoI	$\sigma_{\rm Co}$	NiI	$\sigma_{\rm Ni}$	SrII	$\sigma_{\rm Sr}$
HD 23351	F3V	0.02	0.13	0.06	0.15	–0.21	0.23	–0.01	0.24	0.03	0.00
HD 23609	F8IV	0.31	0.21	0.08	0.17	0.33	0.15	0.27	0.12	0.06	0.05
HD 23247	F3V	–0.12	0.14	0.06	0.16	–0.01	0.57	–0.04	0.18	0.09	0.05
HD 23732	F4V	0.13	0.16	0.02	0.09	0.17	0.14	0.03	0.20	0.06	0.03
HD 23511	F4V	0.23	0.20	0.08	0.11	–0.30	0.24	0.20	0.22	0.12	0.04

HD	SpT	YII	$\sigma_{\rm Y}$	ZrII	$\sigma_{\rm Zr}$	⟨BaII⟩	$\sigma_{\rm Ba}$
HD 23351	F3V	0.11	0.08	0.19	0.20	0.83	0.22
HD 23609	F8IV	0.14	0.08	0.22	0.13	0.74	0.22
HD 23247	F3V	–0.02	0.11	0.37	0.20	0.66	0.21
HD 23732	F4V	0.06	0.12	0.31	0.13	0.76	0.23
HD 23511	F4V	0.11	0.16	0.65	0.34	0.80	0.25